Nicor Gas

Illinois Commerce Commission
2019 Gas Pipeline Safety Conference
Corrosion Basics

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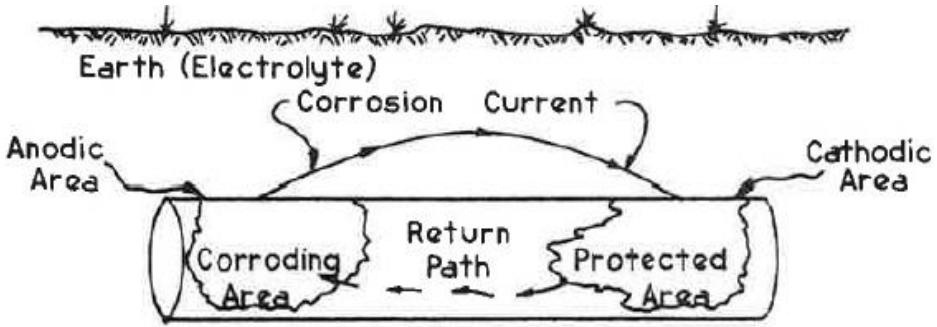
Fundamentals of Corrosion

Fundamentals of Corrosion - Corrosion Cell

Corrosion of underground piping occurs when electric currents leave the pipe and flow into the earth.

Four components are required for corrosion of underground piping to occur.

1. An anode or anodic (corroding) area
2. A cathode or cathodic (protected) area
3. An electrolyte (current carrying medium; soil)
4. A return path for the current (the pipe steel)



Fundamentals of Corrosion - Corrosion Cell

Once the four parts of a corrosion cell are satisfied several types of corrosion could happen.

Bi-metallic/galvanic corrosion (dissimilar metals electrically joined).

Metal Impurity

Mill Scale

Oxygen differentials

Concentration of soils chemicals (differentials)

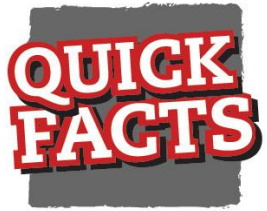
Scarred surface

Bacteria

Stray currents

Fundamentals of Corrosion - Corrosion Cell

To reduce damage from the types of corrosion mentioned the following procedures may be applicable



Bi-metallic/galvanic corrosion (dissimilar metals electrically joined)

- Do not connect different metals together with out the use of isolating fittings.
- Install cathodic protection (below ground only).

Metal Impurity

- Clean and wrap the pipe
- Install cathodic protection

Mill Scale

- Clean and wrap the pipe
- Install cathodic protection

Oxygen differentials

- Clean and wrap the pipe
- Install cathodic protection

Metal Couples that Tend to Cause Galvanic Corrosion

Anodes	When Connected To	Cathodes
Steel		Cast Iron
Steel		Copper
New Steel		Old Rusty Steel
Steel		Brass
Steel		Malleable Steel
Steel		Mill Scale
Cast Iron		Copper
Cast Iron		Graphite Flakes
Cast Iron		Brass
Magnesium		Steel
Aluminum		Steel
Zinc		Black Steel

Fundamentals of Corrosion - Corrosion Cell

To reduce damage from the types of corrosion mentioned the following procedures may be applicable

Concentration of soils chemicals (differentials)

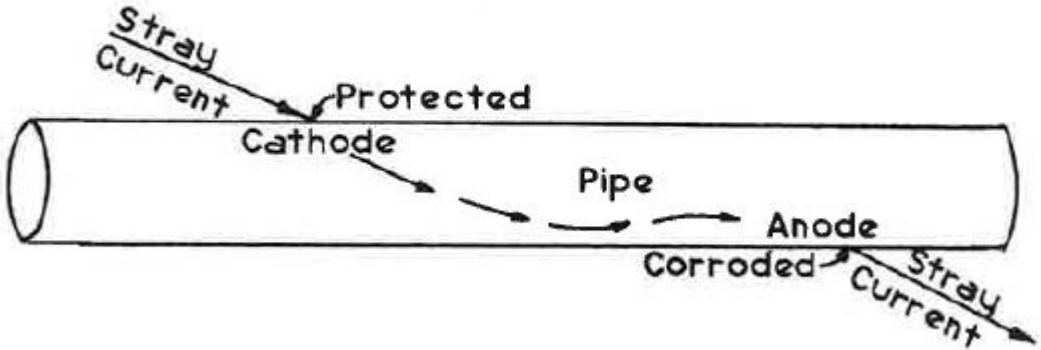
Clean and wrap the pipe
Install cathodic protection

Scarred surface

Clean and wrap the pipe
Install cathodic protection

Bacteria

Clean and wrap the pipe
Install cathodic protection



Stray currents

Connect a bond wire between the structures to return the current to the originating structure. This is to be done under the direction of a corrosion SME. It may also be necessary to install additional cathodic protection.

Fundamentals of Corrosion - Coatings

Coatings are used to insulate the pipe from the earth to eliminate the basic corrosion cell.

Coating types (below ground) Coal Tar, Extruded Polyethylene and Fusion Bonded Epoxies

The effectiveness of the coating is critical in that the more effective the coating the more economical the application cathodic protection.

Care of the coating is important to reduce the magnitude of current required for cathodic protection

Unfortunately, coatings can be damaged during construction, or improperly applied during remediation causing holidays (holes or breaks) where corrosion can occur.

Fundamentals of Corrosion - Coatings

- To prevent corrosion on coated pipe, cathodic protection currents are applied and result in a build up of hydrogen film at the holiday.

- The more holidays in a coating, the more current is needed, resulting in a shorter life for sacrificial anode system or increased costs to supply current through the impressed current system.

Fundamentals of Corrosion - Cathodic Protection

- Protection of underground piping occurs when current flows to the pipe from the earth.
- Cathodic protection is designed to produce a condition in which sufficient current flows to the pipeline from the earth (current sources are attached to the pipeline).

  - Sacrificial Anodes (Magnesium)
    - In a sacrificial anode system, the protective current leaving the anode consumes the anode material. Current magnitude determines the life of the anode

  - Impressed current (Rectifier)
    - In a impressed current system, the protective current flowing from the ground-bed consumes the anodes. Anode material selected, current magnitude, and environmental considerations will determine the life of the anodes

Fundamentals of Corrosion - Cathodic Protection

Definition - Cathodic Protection (CP)

A technique to reduce the corrosion of a metal surface by making that surface the cathode of an electro - chemical cell

Two basics methods of applying cathodic protection

Galvanic Anodes - creates a natural potential difference between itself and the piping to be protected.

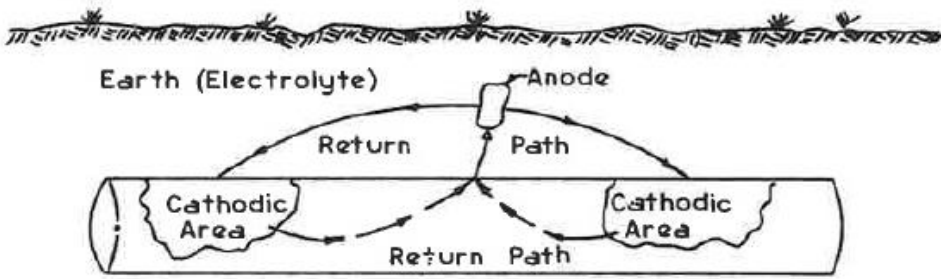


Figure 17: Sacrificial Anode Systems

Two basics methods of applying cathodic protection

Impressed Current Systems - A rectifier converts AC power to DC power. The DC is then impressed through the anode bed and into the soil on to the pipe.

Negative to the “structure”

Positive to the “anode bed”

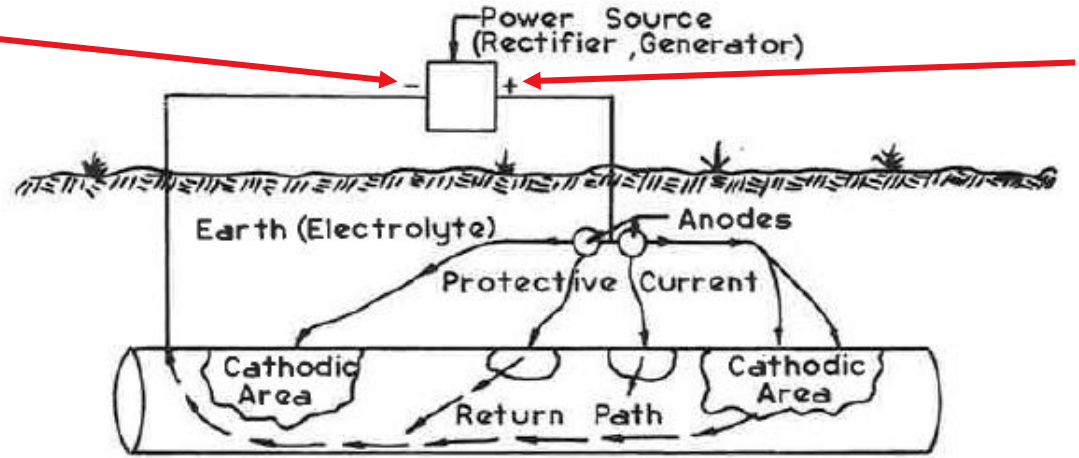


Figure 18: Impressed Current System

Fundamentals of Corrosion - Cathodic Protection (“Criteria”)

Definition - Cathodic Protection Criteria

Standard for assessment of the effectiveness of cathodic protection criteria.

Three Primary Methods (PHMSA Small Gas Operators Manual states 5 methods)

-850mV(CSE) with the current applied (Galvanic Anode Systems)

A polarized potential of -850mV(CSE) (Rectified or Galvanic Anode Systems)

100mV of polarization (Rectified or Galvanic Anode Systems)

CSE – Saturated copper-copper sulfate reference electrode

Fundamentals of Corrosion - Cathodic Protection (“Criteria”)

-850mV(CSE) with the current applied (Galvanic Anode Systems)

A negative (cathodic) potential of a least 850mV with the CP applied. This potential is measured with respect to a saturated copper-copper sulfate reference electrode contacting the electrolyte(soil). Voltage drop other than those across the structure-to-electrolyte must be considered for valid interpretation of the voltage measurement.

Consideration is understood to mean application of sound engineering practice in determining the significance of voltage drops by methods such as.

Measuring or calculating the voltage drop(s)

Reviewing the historical performance of the CP system

Evaluating the physical and electrical characteristics of the pipe and its environment

Determining whether there is physical evidence of corrosion

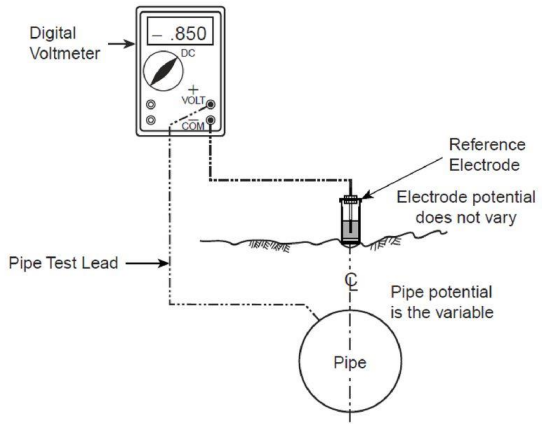
Fundamentals of Corrosion - Cathodic Protection (“Criteria”)

A polarized potential of -850mV(CSE) (Rectified or Galvanic Anode Systems)

Adequate protection is achieved with a negative polarized potential of at lest 850mV related to a saturated copper copper sulfate reference electrode. The polarized potential is defined as the potential across the structure /electrolyte interface that is the sum of the corrosion potential and the cathodic polarization.

The polarized potential is measured directly after the interruption of all current sources and is often referred to as the off or instant off potential.

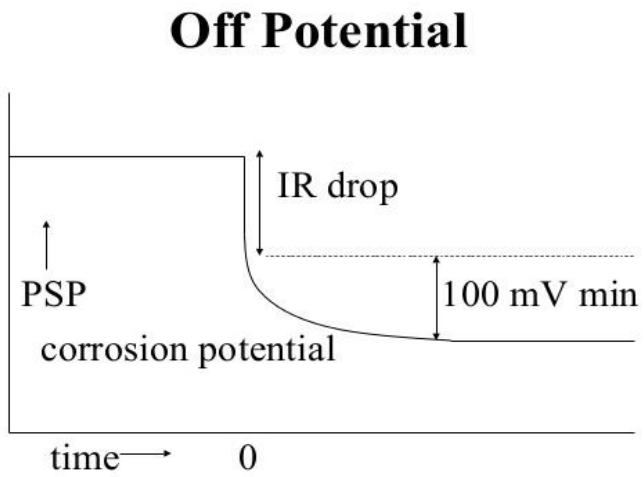
Structure-to-Electrolyte Potential



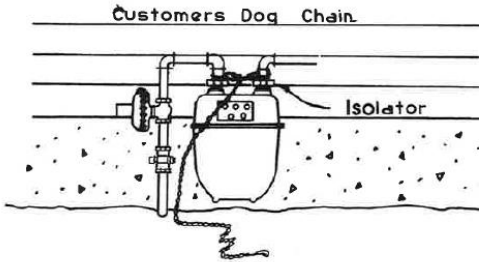
Fundamentals of Corrosion - Cathodic Protection (“Criteria”)

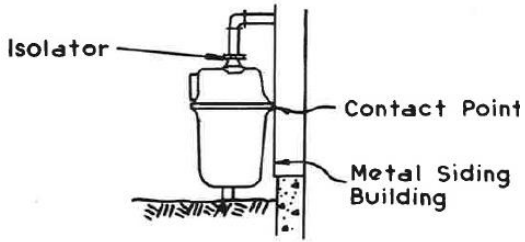
Adequate protection is achieved with “a minimum of 100mV of cathodic polarization between the structure surface and a stable reference electrode contacting the electrolyte.

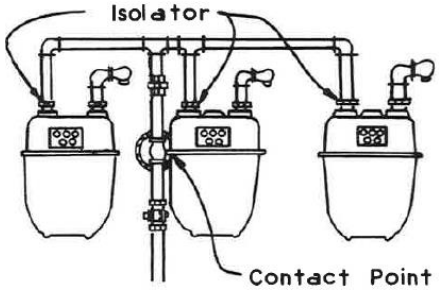
The formation or decay of polarization can be measured to satisfy this criteria.

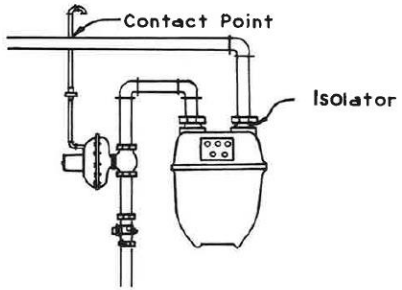


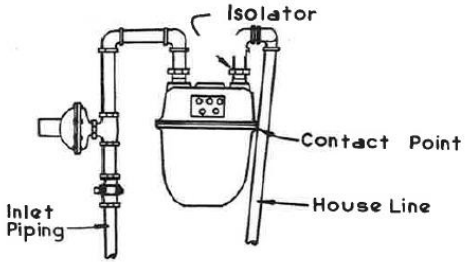
Fundamentals of Corrosion – Common Problems (Aboveground)



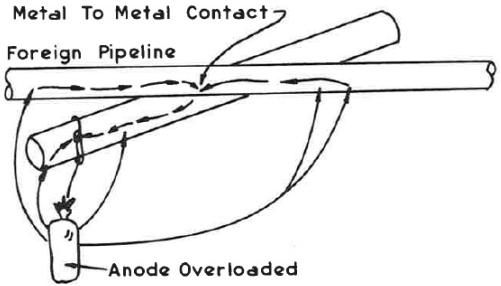


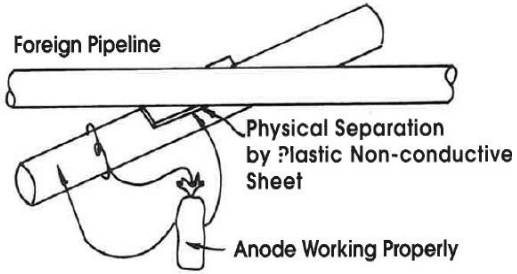


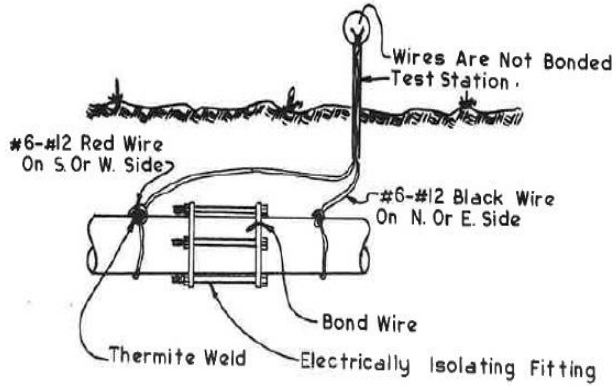




Fundamentals of Corrosion – Common Problems (Belowground)







CFR 192 Subpart I Requirements for Corrosion Control (48 Years)

Subpart I - Corrosion Control

Corrosion control requirements for pipelines installed after July 31st, 1971.

All buried metallic pipe installed after July 31, 1971, must be properly coated and have a cathodic protection system designed to protect the pipe in its entirety.

Newly constructed metallic pipelines must be coated before installation and must have a cathodic protection system installed within one year!

It is recommended that (CP) be installed and operating as soon as possible.

However, if the operator can demonstrate by tests, investigation, or experience in the area of application, including, as a minimum, soil resistivity measurements and tests for corrosion accelerating bacteria, that a corrosive environment does not exist, no cathodic protection is required.

PHMSA

Corrosion control requirements for pipelines installed before August 1st 1971.

Metallic pipelines installed before August 1, 1971, (bare pipe or coated pipe), must be cathodically protected in areas that are determined to be experiencing active corrosion.

All underground natural gas distribution systems, including underground piping related to regulating and measuring stations, must be cathodically protected in areas of active corrosion.

The operator must determine areas of active corrosion by (a) electrical survey, (b) where electrical survey is impractical, by the study of corrosion and leak history records, or (c) by leak detection surveys.

Active corrosion means continuing corrosion, which, unless controlled, could result in a condition that is detrimental to public safety.

Subpart I – Corrosion Control

Corrosion control requirements for pipelines installed before August 1st 1971.

As a guideline for operators when determining corrosion to be detrimental to public safety (active corrosion), OPS recommends the following: OPS recommends that operators of small gas systems and their consultants use the following guidelines in determining where it is impractical to do electrical surveys to find areas of active corrosion where:

The pipeline is covered by concrete or paving and is more than 2 feet from the edge of a paved street or within wall to wall pavement areas.

The pipelines in a common trench with other metallic structures.

Stray earth gradient currents exist (due to telluric currents, iron ore deposits, AC induction, and other sources).

Pavement and congestion prevents ready access to the soil around the pipe.

Facilities are not electrically isolated, are often in direct contact with other metallic structures or in indirect contact.

Current may be shielded by nearby objects close to the pipeline.

Current can be picked up by nearby conducting elements such as casings, parallel or crossing lines, scrap metal, or other foreign objects.

Insufficient history and details of facilities exist.

There is extremely dry soil.

There are adjacent underground facilities.

COATING REQUIREMENTS

All metallic pipe installed above and below ground, as a new or replacement pipeline system, should be coated in its entirety.

EXAMINATION OF EXPOSED PIPE

Whenever buried pipe is exposed or dug up, the operator is required to examine the exposed portion of the pipe for evidence of corrosion on bare pipe or for deterioration of the coating on coated pipe.

A record of this examination must be maintained. If the coating has deteriorated or the bare pipe has evidence of corrosion, remedial action must be taken.

The excavation must be widened to expose more pipe to determine if that pipe also requires remedial action.

The operator must continue to expose pipe until pipe not requiring remedial action is uncovered.

CRITERIA FOR CATHODIC PROTECTION

Operators must meet one of five criteria listed in Appendix D of 49 CFR Part 192, to comply with the pipeline safety regulations for cathodic protection.

Three Primary Methods (PHMSA Small Gas Operators Manual states 5 methods)

-850mV(CSE) with the current applied (Galvanic Anode Systems)

A polarized potential of -850mV(CSE) (Rectified or Galvanic Anode Systems)

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CSE – Saturated copper-copper sulfate reference electrode

MONITORING

A piping system that is under cathodic protection must be monitored. Tests for effectiveness of cathodic protection must be performed at least once every year, not to exceed 15 months between tests.

Short, separately protected service lines or short, protected mains (not over 100 feet in length) may be surveyed on a sampling basis. At least 10 percent of these short sections and services must be checked each year so that all short sections in the system are tested in a 10-year period.

Steel service lines connected to, but electrically isolated from, cast iron mains.

Steel service risers that have cathodic protection provided by an anode attached to a riser that is installed on plastic service lines.

Records of this monitoring must be maintained

OPS recommends, if a small number of isolated protection sections of pipeline exist in the system, that the operator include all sections in the annual survey. If there are a considerable number, they can be sampled at a rate of 10% per year, but this 10% sample must be distributed all over the system.

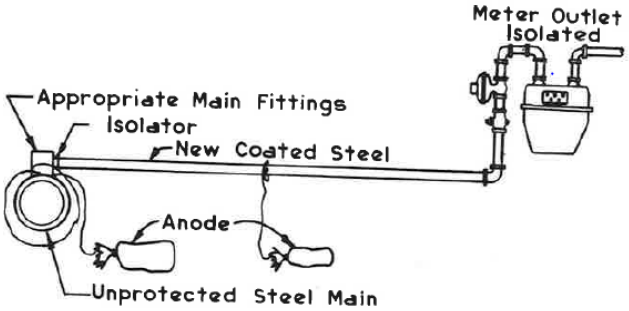
When using rectifiers to provide cathodic protection, each rectifier must be inspected six times every year to ensure that the rectifier(s) is properly operating. The interval between inspections must not exceed 2½ months.

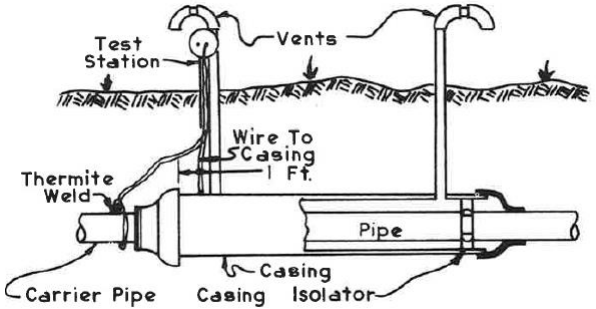
Records of these inspections must be maintained

Operators must take prompt action to correct any deficiencies indicated by the monitoring.

ELECTRICAL ISOLATION

Pipelines must be electrically isolated from other underground metallic structures (unless electrically interconnected and cathodically protected as a single unit).



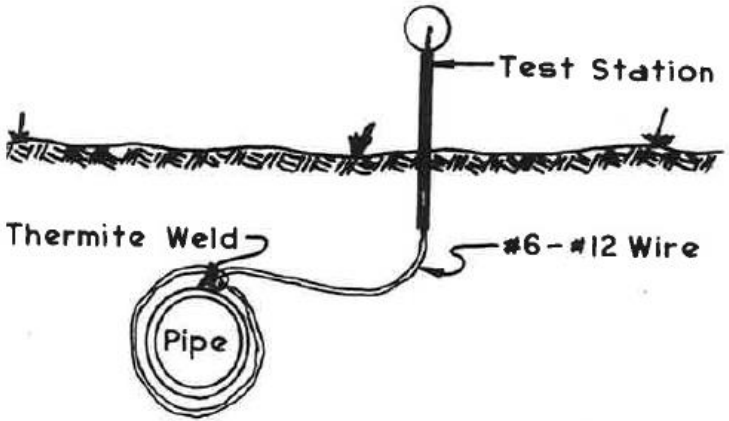


TEST POINTS

Each pipeline under cathodic protection must have sufficient test points for electrical measurement to determine the adequacy of cathodic protection.

Test points should be shown on a cathodic protection system map. Some typical test point locations include the following.

Meter risers
Pipe casing installations
Foreign metallic structure crossings
Insulating joints
Road crossings



INTERNAL CORROSION INSPECTION

Whenever a section of pipe is removed from the system, the internal surface must be inspected for evidence of corrosion.

Remedial steps must be taken if internal corrosion is found. Adjacent pipe must be inspected to determine the extent of internal corrosion.

Records of these inspections must be maintained

ATMOSPHERIC CORROSION

Newly installed aboveground pipelines must be cleaned and coated or jacketed with a material suitable to prevent atmospheric corrosion.

Aboveground pipe, including meters, regulators and measuring stations, must be inspected for atmospheric corrosion at least once every three years, not to exceed 39 months between inspections.

Remedial action must be taken if atmospheric corrosion is found.

Records of these inspections must be maintained.

REMEDIAL MEASURES

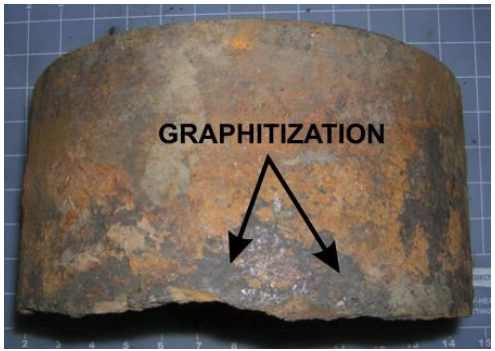
All steel pipe used to replace an existing pipe must be coated and cathodically protected.

Each segment of pipe that is repaired because of corrosion leaks must be cathodically protected.

The new segment should be insulated from any of the existing pipe that will not also be cathodically protected

GRAPHITIZATION OF CAST IRON

Cast iron is an alloy of iron and carbon (graphite). Graphitization is the process by which the iron in cast iron pipe corrodes, leaving a brittle sponge-like structure of graphite flakes. There may be no appearance of damage, but the affected area of the pipe becomes brittle.
For example, a completely graphitized buried cast iron pipe may hold gas under pressure but will fracture under a minor impact, such as being hit by a workman's shovel.



Each segment of cast iron or ductile iron pipe with graphitization (to a degree where a fracture or any leakage might result) must be replaced with steel or plastic and may not be replaced with cast, wrought, or ductile iron. Among other factors, pipeline age and material are significant risk indicators. Pipelines constructed of cast and wrought iron, as well as bare steel, are among those pipelines that pose the highest-risk to safety and should be considered for replacement.

RECORDS

Operators must maintain records or maps of their cathodic protection system. Records of all tests, surveys, or inspections required by the pipeline safety code must be maintained.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